

REMARKS

The Final Office Action dated March 30, 2010 has been carefully considered. Claims 1, 3, 7 and 8 have been amended. Claims 5 and 6 have been canceled. Claims 1-4 and 7-9 are in this application.

Claims 1-4, 6, 8 and 9 are rejected under 35 U.S.C. § 102(b) as being anticipated by U.S. Patent Application Publication No. 2001/0033971 to Zhao et al. and evidenced by U.S. Patent Application Publication No. 2010/0047161 to Latturner et al.

Claim 1 is amended to include the limitation of a solvent from original claim 5. The solvent is not disclosed in Zhao et al. and the liquid electrolyte of claim 1 is different from the electrolyte of Zhao et al. in its structure. Accordingly, each of the limitations of the present claims is not taught or suggested in Zhao et al. and the invention defined by the present claims is not anticipated.

Claim 5 is rejected under 35 U.S.C. § 103(a) as being unpatentable over Zhao et al. as evidenced by Latturner et al. as applied to claims 1-4, 6, 8 and 9 above, and further in view of newly cited U.S. Patent Application Publication No. 2003/0219647 to Wariishi.

Applicants submit that batteries using solid sodium and solid sulfur as a material for an electrode have never been taught or suggested prior to filing of this application, and have been initially published in U.S. journal "Electrochemical and Solid-State Letters, 2006, A123, by the present inventors after the present application was filed (See Enc. 2 Cheol-Wan Park, Jou-Hyeon Ahn, Ho-Suk Ryu, Ki-Won Kim, and Hyo-Jun Ahn, "Room-Temperature Solid-State Sodium/Sulfur Battery" *Electrochemical and Solid-State Letters*, 9(2006) A123-A125). It is commonly known in the related art that lithium/metal sulfur batteries are operated only under high temperature, and Zhao et al. also disclose this feature in paragraph [0003]. However, sodium/metal sulfide batteries are not taught or suggested in Zhao et al., and, in particular, sodium/metal sulfide batteries operating under high temperature were not taught or suggested in Zhao et al.

Since the related-art sodium/sulfur battery is used under high temperature and the sodium and the sulfur of the related-art sodium/sulfur battery are in a liquid state, there may be risks of corrosion and explosion. In order to manufacture a battery with solid sodium and solid sulfur, an

operation temperature of the battery should be under the melting point (97.9 °C) of the sodium and the melting point (112.8°C) of the sulfur. However, if the sulfur is solidified, there is a problem that it is impossible to manufacture an electrode due to the low electrical conductivity of the sulfur. Also, the electrode should be made taking into account several factors such as solubility and ion conductivity of the electrolyte in the sodium, sulfur, and sulfur compound.

Zhao et al. disclose using a CS compound in order to solve the problems of general sulfur. Zhao et al. disclose that the positive electrode contains carbon and sulfur. However, the CS compound recited in Zhao et al. is a compound that contains C and S, which is different in its chemical and physical properties from sulfur used in the sulfur electrode of claim 1 of the present invention.

Sulfur is a chemical element that has the atomic number 16 and the atomic weight 32.066g/mol and has the following physical properties which are described in the Declaration of Hyo-Jun Ahn and Wikipedia as:

Physical properties	
Phase	solid
Density (near r.t.)	(alpha) 2.07 g·cm ⁻³
Density (near r.t.)	(beta) 1.96 g·cm ⁻³
Density (near r.t.)	(gamma) 1.92 g·cm ⁻³
Liquid density at m.p.	1.819 g·cm ⁻³
Melting point	388.36 K, 115.21 °C, 239.38 °F
Boiling point	717.8 K, 444.6 °C, 832.3 °F
Critical point	1314 K, 20.7 MPa
Heat of fusion	(mono) 1.727 kJ·mol ⁻¹
Heat of vaporization	(mono) 45 kJ·mol ⁻¹
Specific heat capacity	(25 °C) 22.75 J·mol ⁻¹ ·K ⁻¹

In contrast, the CS compound recited in Zhao et al. has the following physical properties, which is disclosed in Zhao et al. at ¶¶ [0049], [0093] and [0094] :

Properties of Polycarbon sulfide	
Molecular formula	-Sm- ($m \geq 3$)
Boiling point	(CS _{4.9}) _n : 122.7 °C, (CS _{1.06}) _n : 314 °C
Electrical conductivity	(CS _{4.9}) _n : less than 10-11S/cm, (CS _{1.06}) _n : 5×10^{-7} S/cm
Density (25°C)	(CS _{2.6}) _n : 2.047 g/cm ³ , (CS _{1.06}) _n : 1.903 g/cm ³
Weigh loss : 5% or less from R.T to 300 °C	
Excellent thermal stability, high crystallinity	

Properties of CS ₂	
Molecular formula	CS ₂
Molar mass	76.139 g/mol
Appearance	colorless liquid impure: light-yellow
Density	1.261 g/cm ³
Melting point	-110.8 °C, 162 K, -167 °F
Boiling point	46.3 °C, 319 K, 115 °F
Solubility in water	0.29 g/100 g (20 °C)
Refractive index (n _D)	1.6295

Applicants submit that the positive electrode of claim 1 of the present invention is a sulfur electrode, whereas the positive electrode of Zhao et al. is a CS electrode. As described in paragraph [0003] of Zhao et al., the sulfur electrode has an energy density as high as 1675 mAh/g theoretically, but sulfur is highly insulating and poor in reversibility. Therefore, it is difficult to use the CS compound for an electrode. However, the present invention overcomes this problem and provides a Na/S battery having an excellent electrostatic capacity by using the sulfur for the positive electrode. To achieve this, the present invention uses an electrolyte having a specific solvent and uses sulfur for a positive electrode, as recited in amended claim 1.

Referring to Fig. 2 of the present application, the Na/S battery recited in claim 1 of the present invention has a reaction voltage of 2.18V and 1.7V and a capacity of 663 mAh/g.

However, Zhao et al. do not disclose or suggest any detailed experiment or properties relating to the Na/CSn battery.

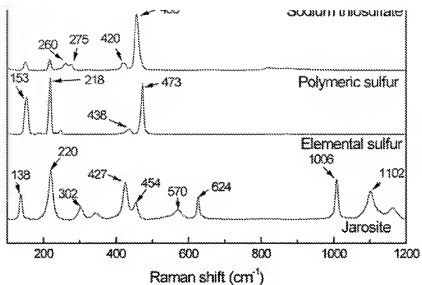
Referring to Fig. 7, Zhao et al. merely mention a Li/CSn+NiS battery. However, the Li/CSn+NiS battery defined in Zhao et al. is different from the Na/S battery defined in amended claim 1 of the present invention.

Applicants submit that even though Zhao et al. disclose that sodium can be used for a negative electrode in paragraph [0059], Zhao et al. do not teach or suggest an experiment in which the sodium is actually used. Also, the Li/CSn+NiS battery experimented in Zhao et al. has a negative electrode of Li, which is different from Na in its flat voltage.

The theoretical capacity of sulfur is 1675 mAh/g and the theoretical capacity of polycarbon sulfide is 550-890 mAh/g, and thus they have different ranges. The theoretically high energy density of sulfur, 1675 mAh/g (as described in paragraph [0003] of Zhao et al.), is achieved by reaction of sodium and sulfur. That is, $2\text{Na} + \text{S} \rightarrow \text{Na}_2\text{S}$ (reaction of two electrons per one atom of sulfur) and the flat voltage obtained due to this reaction has a flat section at 1.7V as shown in Figs. 1 and 2.

However, in the case of $(\text{CS}_x)_n$ compound, the carbon C does not contribute to the reaction and only the sulfur (S) contributes to the reaction and thus the theoretical energy density falls between 550 mAh/g and 890 mAh/g and is much lower than the sulfur electrode (see paragraph [0050] of Zhao et al.).

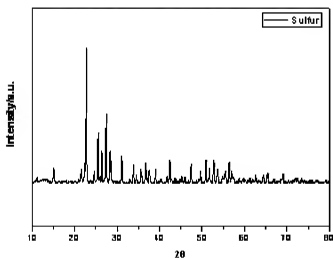
The CS recited in Zhao et al. is different from sulfur in its raman shift as illustrated in Figs. 1, 4, and 5 of Zhao et al. The raman shift of sulfur is as follows:



Raman shift (sulfur) = 153, 218, 438, 473

As described in J. I. Xia et al. Hydrometallurgy, 100, (2010) 129-135

Zhao et al. illustrate the X-ray diffraction pattern of CS, which is different from the X-ray diffraction pattern of sulfur as follows:



As described above, CS and S are different materials and thus it is difficult for one of ordinary skill in the art to derive the battery of the present invention from the teachings of CS disclosed in Zhao et al.

Also, Zhao et al. do not disclose an embodiment in which a battery is manufactured with a sodium electrode along with a (CS_x)_n electrode and thus, one of ordinary skill in the art would not know from Zhao et al. whether a battery could be manufactured with a sodium electrode. Although discharge capacities when CS_x/n is used for a positive electrode and lithium is used for a negative electrode are shown in Table 1 of Zhao et al., they are much lower than in a battery manufactured with lithium and sulfur electrodes.

Referring to comparative examples 1 and 2 of Zhao et al., different effects are obtained even if the same organic sulfur compound (CS compound) is used. Therefore, one of ordinary skill in the art would not expect the effect of the solid sulfur electrode of the present invention based on the organic sulfur compound electrode of Zhao et al.

Also, in Zhao et al., alkali metals such as lithium and sodium may be used for a negative electrode (see paragraph [0059]) and the negative electrode may be manufactured in the form of a porous metal body (see paragraph [0060]). However, these teachings do not teach or suggest that the negative electrode including sodium can be manufactured in a solid state. Applicants submit that a metal negative battery such as a lithium battery using solid lithium and operating under high temperature and a lead battery using solid lead and operating under high temperature was generally known in the related art prior to filing of this application. A sodium battery using liquid sodium and operating over 300°C was also known in the related art prior to filing of this application. However, there is no teaching or suggestion of a battery using a solid-type sodium negative electrode and Zhao et al. also do not clearly teach using the solid-type sodium negative electrode, as recited in amended claim 1.

Further, the Examiner states that Wariishi discloses liquid electrolytes similar some of solvents of the electrolyte recited in claim 1 of the present invention. However, Wariishi does not teach or suggest the liquid electrolytes of the present claims. And also, Wariishi fails to teach the Na/S battery as recited in claim 1 of the present invention and does not cure the deficiencies of Zhao et al. noted above. Moreover, since the positive electrode of Zhao et al. is

different from the positive electrode of the present invention, the combination of Zhao et al. and Wariishi does not teach or suggest the invention defined by the present claims and the invention defined by the present claims is not obvious in view of Zhao et al. as evidenced by Latturner et al. in combination with Wariishi.

Claim 7 is rejected under 35 U.S.C. § 103(a) as being unpatentable over Zhao et al. as evidenced by Latturner et al. as applied to claims 1-4, 6, 8 and 9 above, and further in view of newly cited U.S. Patent Application Publication No. 2002/0037457 to Choi.

Choi discloses a lithium battery including a lithium negative electrode, a positive electrode comprising an electrically conductive material and a binder. However, Choi does not teach or suggest the Na/S battery and the liquid electrolytes of the present claims and does not cure the deficiencies of Zhao et al. noted above. Accordingly, the invention defined by the present claims is not obvious in view of Zhao et al. as evidenced by Latturner et al. and further in view of Choi.

In view of the foregoing, Applicants submit that all pending claims are in condition for allowance and request that all claims be allowed. The Examiner is invited to contact the undersigned should she believe that this would expedite prosecution of this application. It is believed that no fee is required. The Commissioner is authorized to charge any deficiency or credit any overpayment to Deposit Account No. 13-2165.

Respectfully submitted,



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